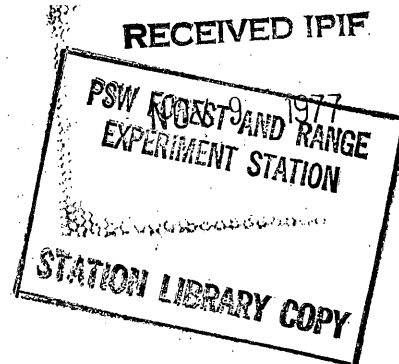


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Ohia decline research report

Richard P. Papp

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OHIA DECLINE RESEARCH REPORT, 1976-77<sup>1</sup>

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- 
1. Results from Cooperative Agreement 21-380 from the U.S. Forest Service to the Bishop Museum, entitled "Studies on Plagithmysus and other insect borers of ohia and other trees in relation to ohia forest decline (Work Unit No. 1205)".
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## Table of Contents

	Page
Introduction.....	1
Association of <u>P. bilineatus</u> with ohia decline.....	3
Ohia decline rating system.....	10
Transect decline severity.....	13
Aspects of <u>P. bilineatus</u> life history.....	17
<u>P. bilineatus</u> larval implantation.....	19
Artificial girdling study.....	21
Attractants for <u>P. bilineatus</u> .....	24
<u>P. bilineatus</u> activity in ohia slash.....	26
Summary.....	29
References.....	30

# LIST OF TABLES

Table No.		Page No.
1.	Frequency of <u>Plagithmysus bilineatus</u> - attacked ohia trees in different crown loss percent groups...	5
2.	Frequency of <u>Plagithmysus bilineatus</u> - attacked ohia trees in groups determined by percentage of remaining functional crown foliage (FCF).....	7
3.	Frequency of <u>Plagithmysus bilineatus</u> attacks in ohia trees grouped by percentage of remaining functional crown foliage (FCF).....	8
4.	Average health of ohia trees on decline transects..	14
5.	Relative rate of change in decline severity on different transects.....	15
6.	Crown loss and functional crown foliage in girdled ohia trees.....	22
7.	<u>Plagithmysus bilineatus</u> activity in ohia slash.....	27

## INTRODUCTION

This report is a summary of continuing research conducted under Cooperative Agreement no. 21-380, between the U.S. Forest Service, Institute of Pacific Islands Forestry, and the Bernice P. Bishop Museum. Because of the length of time required for completion of field work and experiments in ohia decline studies, this report necessarily reflects both the status of ongoing projects as well as the results of projects already completed.

It has been some two years now since a full time field entomologist (Papp) has been assigned to ohia decline research, working closely with U.S. Forest Service personnel. By way of introduction to this report, this might be an appropriate time to restate the research objectives, as outlined in the co-operative effort which began in July, 1975. These objectives were to:

1. Determine the incidence of Plagithmysus and other borers in ohia-koa rain forests in Hawaii, their endemic and epidemic population dynamics, and their role in epidemic forest decline.
2. Determine the incidence of attack and rate of girdling of ohia trees by Plagithmysus borers in relation to size and "health" class of tree.
3. Determine more precisely the prominence of woodborers in ohia forest decline relative to other identified organisms associated with ohia.

Upon the arrival of the Bishop Museum field entomologist in Hawaii

in 1975, a major research effort was already being prepared to determine the association of a root fungus, Phytophthora cinnamomi, and a cerambycid beetle Plagithmysus bilineatus Sharp with ohia decline (Smith et al., 1976, Study Plan 4610.04). This research was begun in September 1975 and has occupied the major portion of research time and effort. Preliminary results of this study have been reported recently (Papp, 1976, Kliejunas et al., 1977). All of the previously stated objectives are attempted at least in part by these efforts.

In addition to work conducted directly under study plan 4610.04, other exploratory studies were begun and conducted in 1975-76 involving larval implantations of P. bilineatus into healthy ohia trees, populations of P. bilineatus developing in ohia slash, and artificial girdling of healthy ohia trees. Some of this work has continued into the present year, and will be summarized later in this report.

Finally, several new cooperative research efforts have been initiated during the past year. These include studies of mortality of P. bilineatus associated with the injection of selected systemic insecticides into ohia trees (Stein and Papp), generation time of P. bilineatus along an altitudinal gradient in the Hilo watershed (Papp and Stein, study plan 4610.06), and relative abundance of 3 species of scolytid beetles at different elevations in the Hilo watershed (Papp and Samuelson). There are no reportable results in these incipient projects as yet.

## ASSOCIATION OF P. BILINEATUS WITH OHIA DECLINE

The initial field work for this research, which was conducted following study plan 4610.04, was begun in September 1975 at the Tree Planting Road transect (TPR-3) and completed in August 1976 at the Kahaluu transect (KAH-1). Following transcription of data from field forms onto data input forms, the data was key punched onto cards. Finally, an IBM tape with the raw data was submitted to David Sharpnack, a U.S. Forest Service statistician at PSW in Berkeley, California. A preliminary analysis of this data (Sharpnack, 1977) was received in March, 1977.

A full screen analysis program called WINNON using 5 dependent variables (terminal growth, leaf retention, crown loss percent, crown chlorosis percent and crown loss plus crown chlorosis percent) and 10 independent variables was run with 800 transect tree observations. Although all regression relationships were highly significant, standard errors of estimate were also very high. Using this analysis, no screening of variables was possible, nor was the high level of statistical significance considered to be of much interest (Sharpnack, 1977).

At a meeting in Hilo on 24 March 1977 Hodges, Holtzman, Fujioka, Kliejunas and Papp reviewed results of the preliminary analysis. It was decided to run regressions on a site-by-site basis using only crown loss percent as a dependent variable. Since crown chlorosis percent readings are based on percent of remaining crown for each tree, the variables based on chlorosis percent alone or simply added to the percent crown loss are meaningless (see section on transect rating).



Measures of leaf retention and terminal growth were not considered to be reliable estimates of tree condition, and were subsequently dropped from further consideration.

For Plagithmysus bilineatus association, regressions using crown loss percent as a dependent variable and number of galleries and number of gallery spirals, respectively, as independent variables were run by Francis Fujioka (U.S. Forest Service, IPIF) for each of the eight transect locations. Using this analysis, regressions with crown loss percent versus number of galleries were shown to be highly significant at all of the transect sites except Laupahoehoe. (It should be noted that the Laupahoehoe transect is unique in that the ohia trees there are also infested with the introduced banana poka vine (Passiflora mollissima) which is another variable probably related to crown loss at that site). However, as with the full screen analysis program, high standard errors of estimate were evident in all regressions, i.e. there is a great deal of data point "scatter" around the regression lines, making it difficult to interpret number of Plagithmysus bilineatus galleries alone as closely related to percent crown loss.

During the period when the full screen analysis of the transect data was proceeding at Berkeley, data on the distribution of transect trees with P. bilineatus galleries in crown loss percent groups were manually extracted from field data and summarized (Table 1). As one reads down the table, from "healthy" to severely declining trees, the proportion of trees with galleries tends to increase with increasing

crown loss. This appears to be a direct linear relationship when insect attack data for all transects are considered together, in spite of obvious site differences among transect locations.

Crown chlorosis percentages can be combined mathematically with crown loss (see section of transect rating) to generate a percent functional crown foliage (FCF) for each transect tree. Transect trees can then be grouped according to FCF values, which represent percent of healthy crown foliage. A summary of trees in each FCF group or health class with galleries is given in Table 2. It is apparent that an inverse linear relationship exists between tree health (as evaluated by crown symptoms) and incidence of galleries.

Another way of looking at the relationship between P. bilineatus and tree health is to compare distribution of trees in FCF groups with number of galleries occurring on trees in those groups (Table 3). Here again there appears to be an inverse linear relationship between tree health indicated by crown symptoms and incidence of P. bilineatus attack as indicated by number of galleries present.

It should be noted, however, that in spite of the apparent close relationship between crown condition and the incidence of P. bilineatus attack, a significant proportion of the severely declining trees (31 out of 122, or 26.4%) show no evidence of prior insect attack. At the Laupahoehoe transect (LAU-3) more than half (14 of 27) of the severely declining trees (FCF  $\leq$  10%) had no P. bilineatus galleries. Even if these transect data are eliminated from further consideration due to the extensive presence of banana poka vines in the canopy,

17.9% of the severely declining trees in the remaining transects still show no galleries.

There has been continuing discussion as to whether P. bilineatus "is able to successfully attack and kill healthy vigorous trees" (Hodges, 1977, p. 7). Although we cannot yet state with certainty that P. bilineatus attack causes vigorous trees to die, transect field data indicates that this insect can attack healthy trees, and that it can complete development in a healthy host, again with the qualification that crown symptom expression is an indication of vigor. Four trees with only 10% crown loss (1 at LAU-2, 3 at KAU-2) had galleries with adult emergence holes on the main trunk or in main branches. In the 20% crown loss category, 10 trees had galleries with adult emergence holes (5 at KAU-2, 4 at LAU-3, 1 at TPR-3). The point is made that although most adult emergence occurs in moderate or severely declining trees, it is biologically possible for P. bilineatus to complete a life cycle in a "healthy" tree. Since we must destructively sample trees to ascertain the presence of galleries, however, we are unable to monitor the condition of healthy trees following adult emergence.

## OHIA DECLINE RATING SYSTEM

At the present time we have no instrumentation to allow us to accurately assess the current physiological condition or "health" of ohia trees. As an attempt to characterize the appearance of declining trees with respect to crown symptom expression a decline rating system was devised. Using this system the observer visually estimates the condition of the crown with respect to two parameters, crown loss and crown chlorosis.

Crown loss is defined as the percentage of crown foliage missing, as evidenced by the presence of crown branches without leaves. Crown chlorosis is defined as the percentage of foliage in the remaining crown which is discolored. In the context of the current system, dead leaves still attached to crown branches would be considered as chlorotic.

Since field observations over several years indicate that as a tree declines, foliage becomes chlorotic before it is lost, crown loss alone is not sufficient to indicate the condition of a tree. Because of the way in which it is defined, however, crown chlorosis percentages for different trees cannot be directly compared. What is needed, therefore, is a term which a) combines the ratings for crown loss and chlorosis into a single numerical assessment of crown condition, and b) allows valid comparison of the crown condition for different trees.

Burgan and Petteys (1972) have attempted this by devising a "decline index number" (DIN), but it can be demonstrated that DIN does not accurately reflect the actual percentage of healthy crown in a tree. More recently, a collective term called "functional crown foliage" (FCF)

has been derived, as follows:

Let A = % of crown foliage lost

B = % of chlorosis in remaining crown foliage

If  $B_T$  is defined as the percentage of the total crown with chlorotic foliage, then

$$(1) B_T = B(100-A)/100$$

FCF represents the percentage of the total crown in apparently healthy or functional condition. It is equal therefore to the sum of % crown lost plus the % of total crown which is chlorotic, subtracted from 100:

$$(2) FCF = 100 - (A + B_T)$$

Substituting equation (1),

$$(3) FCF = 100 - [A + B(100-A)/100]$$

Simplifying,

$$(4) FCF = 100 - (A + B - AB/100)$$

By computing FCF values for trees with crown loss and crown chlorosis ratings, the crown condition of any two or more trees can be compared directly and easily in a quantitative manner. It is also possible to compute the average condition of a group of trees, such as those along a transect, for comparison to trees on other transects. One can quantitatively monitor the condition of transect trees over a period of time by comparing successive FCF values. Finally, since equation (4) effectively combines the two parameters now used for evaluating tree health, it should probably be the dependent variable of choice in future analyses of decline-related organisms.

It should be emphasized at this point that even this improved method of determining the degree of crown symptom expression does not necessarily reflect the current dynamic state of tree vigor.

Experiments with implantation of P. bilineatus larvae and artificial girdling of ohia trees indicate that crown symptoms usually do not appear for many months (up to 22) following injury. Thus evaluation of crown symptoms is really giving us a picture of the tree's delayed response to stress rather than as assessment of its present vigor.

## TRANSECT DECLINE SEVERITY

When transects for study plan 4610.04 were established in 1975, each of the transect trees was rated for crown loss and chlorosis. Remaining transects were recently rated again to determine the progress or amelioration of decline at each of seven transect sites. Mean values of FCF were calculated for each transect. Table 4 ranks the transects in order of current decline severity. In terms of current crown condition, transects at the Wailuku River Road and the Tree Planting Road exhibit the most severe decline. Trees appear to be somewhat healthier on transects located on the Upper Saddle Road, and in the Ka'u Forest Reserve above Kahuku Ranch. The healthiest transects are in the Olaa Forest Reserve near Volcano, the Kahaluu Forest Reserve in Kona, and in the Puna district. It should be pointed out, however, that even on the healthiest transect (PUN-2) the average tree now shows more than one quarter of its crown foliage in dysfunction.

Another aspect of decline severity is achieved by comparing the rate of change of decline on the different transects (Table 5). In this table transects are ranked according to how much average FCF change has occurred since the initial transects were established. Because of differing time intervals between initial and current ratings, the change has been standardized with respect to rating interval, and then expressed as a multiple of the lowest rate of change, which occurred on the Kahaluu transects. The relative rate of change in the mean functional crown foliage ( $\Delta \overline{\text{FCF}}/\text{month}$ ) simply

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indicates how rapidly decline is increasing or decreasing on a particular transect compared to change on other transects. For example, the average health of trees on Puna transect PUN-1 is declining almost four times as rapidly as on Puna transect PUN-2 ( $-6.3/-1.7 = 3.71$ ).

It should be obvious from table 5 that rates of decline or tree condition improvement are unrelated to average crown condition on the transects. Furthermore, although average crown condition for each of the 2 transects at Kahaluu (KAH-3 and KAH-2) and Olaa (OLA-2 and OLA-3) is improving at approximately the same rate, trees on some other transects which are declining are doing so at quite different rates (e.g. Puna transects previously mentioned). Even at so-called epidemic decline sites such as the Tree Planting Road (TPR-1 and TPR-2) and the Wailuku River Road (WRR-1 and WRR-3), decline seems to be occurring in a spotty fashion within the transects, with no evidence of a discrete moving front of decline.

Tree death has occurred on some of the 100-tree transects since 1975. The greatest mortality has occurred at the Tree Planting Road. Transect TPR-1 now has 11 dead trees, while 15 trees have died on transect TPR-2. On the Wailuku River Road, 8 trees have died on transect WRR-3, and 9 trees on transect WRR-1. On the Kona side, 2 trees have died on transect KAH-2. Except for the Kahaluu transect, all transect tree deaths have occurred in the so-called epidemic decline area in the Hilo watershed.



## ASPECTS OF PLAGITHMYSUS BILINEATUS LIFE HISTORY

A number of aspects of P. bilineatus life history are now becoming evident as a result of the transect data compiled during study 4610.04. Much of this information will be included in a manuscript currently in preparation by Papp. Observations of mating behavior observed at several transect locations, oviposition sites in declining trees, gallery lengths, and estimates of larval mortality are among the topics to be treated.

For the purposes of this report, mention of only a few facets of P. bilineatus biology will be made.

- a. adult activity - Until recently it was assumed that adults were active only during warm sunny weather. This assumption was based on many previous field observations of adults, especially on ohia slash. The usual case is that when weather becomes cloudy or rainy, active adults become motionless, often disappearing altogether. During recent field work on the Tree Planting Road (16 September 1977) however, Stein and Papp observed active adults on week-old ohia slash even during light rainfall. A few individuals were also seen flying under these conditions.
- b. oviposition behavior - Papp has made recent observations of adults on freshly cut standing ohia stumps at several sites. Female adults often appear to follow a spiralling pattern up and down the trunk in searching for oviposition sites. This behavior was sometimes observed even while a male clung to the dorsum of the female, with intermittent copulation occurring.

- c. gallery length - Measurements have been made on over 1600 p. bilineatus galleries in ohia. For the 282 complete galleries in which either a pupal cell or adult exit hole was found (i.e., the larvae had completed their tunnelling in the cambium-phloem) mean gallery length ranged from 114.8 cm at the Tree Planting Road to 205.7 cm at Laupahoehoe. The overall mean gallery length was 167.4 cm. There is some indication that gallery length may be related to altitude, with longer galleries at the higher sites.
- d. Larval mortality - Most of the 1655 galleries examined have been vacant larval galleries (i.e., larvae apparently died and decomposed before pupation). Totaled for all transect sites, 1131 (68.3%) were abortive galleries. Most of this mortality remains unaccounted for.

### P. BILINEATUS LARVAL IMPLANTATIONS

Two preliminary studies involving implantation of P. bilineatus larvae into healthy ohia trees have been briefly described previously (Papp and Samuelson, 1976). Although no additional larvae have been implanted since that time, the study trees located on the Tree Planting Road continue to show the effects of the earlier implants. In most cases where larvae were implanted into branches, foliage distad of the resulting gallery is chlorotic or dead. In trees where larvae were implanted into a main trunk, all foliage above the gallery is chlorotic or dead. Branches beneath the gallery (between it and the ground) remain fully foliated and apparently healthy. As was the case with artificially girdled trees, onset of noticeable crown symptoms did not occur until many months after implantation. For example, a large tree into which a P. bilineatus larva had been implanted in May 1975 began to show extensive chlorosis only in March 1977. At the present time (September 1977) foliage in the entire tree above the gallery on the trunk is chlorotic or dead or missing, while foliage on branches beneath the gallery remains apparently unaffected.

Some differences in symptomology between implanted trees and "typical" declining trees have been noted. For instance, in declining trees the chlorosis is usually more uniform. Certainly the sharp differences in branch foliage condition as seen following larval implants are not commonly observed. Also, there has been no noticeable trunk sprouting (epicormic branching) in the implanted trees,

while typical declining trees often show this. A larger study of this type with replications at several sites may be needed to corroborate these findings, but it appears that although P. bilineatus larvae implanted into healthy trees will cause crown symptoms associated with ohia decline, the pattern of symptom development in the whole tree is atypical of the natural decline pattern.

## ARTIFICIAL GIRDLING STUDY

This study was mentioned briefly in the Ohia Decline Research Report 1975-76 (Papp and Samuelson, 1976). The objective was to determine whether mechanical injury to trees similar to that caused P. bilineatus could cause expression of decline symptoms.

Since chlorosis in some of the girdled trees first appeared in May 1976, the crown condition of the 30 initially healthy study trees (10 with spiral girdling resembling P. bilineatus galleries 'S-girdles', 10 with girdling on one side of the tree only 'Z-girdles', 10 check trees with no girdling) has been monitored at monthly intervals. Table 6 summarizes the crown condition in these trees as of September 1977.

It is obvious that spiral girdling causes expression of severe decline symptoms in ohia trees. In addition to the fact that S-girdled trees now retain less than one third of their crowns in healthy condition, 3 of these trees have died since the study began in September 1975 (2 in May 1977, 1 in August, 1977). No trees in the other categories have died, although slight decline in their condition is also apparent (less so in the check trees).

Current plans are to eventually fell and dissect all 30 trees at the conclusion of the study. Shortly after the trees have been girdled in September 1975, Papp noticed several adult P. bilineatus running on the bark surface near the girdling wounds. One of the S-girdled trees which has since died was recently felled and found to contain more than 20 P. bilineatus galleries, mostly near the wound site.

Thus it is probable that the severely declining S-girdled trees are in fact harboring many P. bilineatus galleries which are in themselves damaging the trees. It remains to be seen if this is also the case with the Z-girdled trees, and if so, why they are not also in severe decline.

ATTRACTANTS FOR P. BILINEATUS

In September 1976 quantities of fresh ohia bark, sapwood and heartwood were collected and returned to the Forestry Research Laboratory in Hilo in large plastic bags. The heartwood and sapwood pieces were separately run through a jointer at the Division of Forestry Baseyard in Hilo and the resulting shavings collected in labeled plastic bags. Portions of heartwood and sapwood shavings, and ohia bark, were later placed separately in a commercial blender and ground up at high speed for several minutes. Some of each of these components were blended with each of the following solvents: acetone, 95% ethyl alcohol, distilled water, n-hexane and glacial acetic acid. The resulting solvent extracts were filtered and poured into 1000 ml polyethylene bottles and refrigerated at 4°C.

In order to test the effectiveness of these solvents in attracting P. bilineatus, Wickman type traps, each consisting of two 20 X 20 cm  $\frac{1}{4}$ " hardware cloth panels coated with tanglefoot insect barrier were constructed. These were suspended about 1.5 m above the ground on heavy wire hung in ohia trees at an elevation of 600 m in the Hilo watershed. Flasks containing either a solvent extract or solvent alone and fitted with a cotton wick was attached to the base of each trap. Each trap was replicated twice, for a total of 40 traps. These were checked daily through December 1976 for P. bilineatus adults.

Although many ohia-associated insects were captured in the traps, including many Homoptera and Scolytidae (Xyleborus spp.), only 4 specimens of Plagithmysus bilineatus were recovered. All of these

were taken on the two traps which contained sapwood extract in 95% ethyl alcohol. The small number of plags taken obviously precludes any evaluation of the attractiveness of the extracts.

Rapid evaporation of some solvents in the field, drying of trap wicks, as well as large amounts of vegetative detritus collecting on the trapping surfaces, may have seriously impaired trap efficiency. Further studies of attractants, if initiated, should probably be conducted in the laboratory, and utilize an olfactometer to measure behavioral response to candidate attractants.



## P. BILINEATUS ACTIVITY IN OHIA SLASH

Results of Plagithmysus bilineatus activity in ohia slash at 7 of the ohia decline transects were reported last year (Papp and Samuelson, 1976). The eighth transect (KAH-1), was cut on 11 August 1976, with slash follow-up on 1-2 December 1976. A summary of all slash activity is given in Table 7. Since the slash examined for new galleries consisted of a portion of the trees already felled in previous transect research (Smith et al., 1976), some comparisons can be made between populations in standing trees and in slash.

One interesting aspect is that if allowance is made for the smaller sample size (only portions of 20 trees at each 100 tree transect were sampled), ohia slash at 5 of the 8 transect sites contained for more P. bilineatus galleries than standing trees at the same site. Trees at the remaining three sites were located at higher altitudes, (USR-1 and LAU-3) or were felled during inclement weather (WRR-2 and LAU-3), where cool temperatures and rain could have appreciably damped adult activity on slash.

Another point is that slash galleries in 7 of the 8 transects contained a much higher proportion of larvae than the standing tree galleries. Again allowing for sample size difference, slash at 6 of the 8 sites also contained for greater numbers of larvae than standing trees. Taken together these points indicate that slash is far more attractive to adult female P. bilineatus than standing trees, regardless of their decline status.

Results of tree dissections on one of the Puna slash transects

also support this hypothesis. In this study, two transects were established immediately adjacent to the PUN-3 transect. These were called "slash transects" since their purpose was to determine whether P. bilineatus breeding in slash from transect PUN-3 would subsequently attack relatively healthy standing trees near the slash. Each of the slash transects were established within a week of the cutting of transect PUN-3. All trees on slash transect R-80 (right side of transect PUN-3, with 80 trees) were felled 28 June to 1 July 1976. Not a single P. bilineatus gallery was found in any of these trees. However, when slash from transect R-80 was examined on 7 March 1977, many new P. bilineatus galleries were found. This would seem to be further evidence that while Plagithmysus bilineatus is indeed a component of the ohia decline syndrome, its usual role is to attack trees which are already severely stressed or wounded.

## SUMMARY

The cerambycid beetle Plagithmysus bilineatus Sharp is an important component of the ohia forest decline syndrome on the island of Hawaii. Its association with declining trees, while not absolute, is consistent at each site studied. P. bilineatus occurs in greatest numbers in severely declining trees, and its populations in standing trees are largest in the region of epidemic decline. As decline of ohia forests on the island intensifies, further increases in P. bilineatus populations may be expected.

There is no question that production of large amounts of slash in ohia forests will cause further build-up of borer populations, but the consequences of this to remaining healthy forests, or to ornamental plantings of ohia, remain to be determined.

Although P. bilineatus cannot be described as the primary cause of ohia decline in Hawaii, it is the only organism thus far studied which occurs very frequently in declining trees and very infrequently in healthy ones. Given the extreme importance of ohia forests to the agricultural and tourist economies of the State of Hawaii, as well as to the unique flora and fauna which inhabit these forests, further study of P. bilineatus and other possible decline-associated organisms is strongly recommended.

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% Crown Loss	Number of trees sampled	Number of trees with galleries	Percent of trees with galleries
0-10	88	11	12.5
11-20	183	26	14.2
21-30	178	58	32.6
31-40	76	22	28.9
41-50	57	25	43.9
51-60	36	25	69.4
61-70	32	18	56.3
71-80	39	30	76.9
81-90	54	38	70.4
91-100	56	42	75.0
Total	799	295	36.9

Table 1. Frequency of Plagithmysus bilineatus - attacked trees in different crown loss percent groups.

Table 2. Frequency of Plagithmysus bilineatus - attacked ohia trees grouped by percentage of remaining functional crown foliage (FCF). Trees are listed in order of increasing health.

% FCF	Number of trees sampled	Number of trees with galleries	% of trees with galleries
≤ 10	122	91	74.6
11-20	51	37	72.5
21-30	39	20	51.2
31-40	52	27	51.9
41-50	63	21	33.3
51-60	118	38	32.2
61-70	143	37	25.8
71-80	147	15	10.2
> 80	64	9	14.1
=====			
Total	799	295	36.9

Table 3. Frequency of P. bilineatus attacks in ohia trees grouped by percentage of remaining functional crown foliage (FCF). Trees are listed in order of increasing health.

% FCF	Number of trees sampled	Total number of galleries in trees sampled	Mean number of galleries in trees sampled	Mean number of galleries in attacked sample trees
≤ 10	122	629	5.2	6.9
11-20	51	249	4.9	6.7
21-30	39	150	3.8	7.5
31-40	52	183	3.5	6.8
41-50	63	95	1.5	4.5
51-60	118	182	1.5	4.8
61-70	143	108	0.8	2.9
71-80	147	30	0.2	2.0
> 80	64	29	0.5	3.2
=====				
Total	799	1655	2.1	5.6

Table 4. Average health of ohia trees on decline transects.  
(Transects are listed in order of decreasing decline severity, based on ratings taken 21 July to 29 August 1977).

TRANSECT	DATE RATED	$\overline{\text{FCF}}^a$
WRR-3	8/29/77	30.3 <sup>b</sup>
WRR-1	7/22/77	34.2
TPR-1	8/19/77	34.9
TPR-2	7/21/77	38.6
USR-3	8/08/77	42.2
USR-2	8/08/77	42.9
KAU-1	8/17/77	43.4
KAU-3	8/17/77	46.8
OLA-3	7/26/77	58.3
OLA-2	8/09/77	60.1
KAH-2	8/18/77	61.5
KAH-3	8/18/77	66.3 <sup>b</sup>
PUN-1	8/25/77	68.8
PUN-2	8/25/77	73.9

a - Mean percentage of healthy crown foliage per transect tree, based on 100 trees.

b - Based on 99 trees.



Table 5. Relative rate of change in decline severity on different transects.<sup>a</sup>

TRANSECT	CURRENT $\overline{\text{FCF}}$	$\Delta \overline{\text{FCF}}/\text{Month} \times 100$	RELATIVE <sup>b</sup> $\Delta \overline{\text{FCF}}/\text{Month}$
PUN-1	68.8	-54.4	-6.3
TPR-1	34.9	-54.2	-6.3
KAU-1	43.4	-47.8	-5.6
WRR-3	30.3	-38.3	-4.5
TPR-2	38.6	-36.5	-4.2
KAU-3	46.8	-31.3	-3.6
PUN-2	73.9	-14.4	-1.7
USR-2	42.9	-11.8	-1.4
WRR-1	34.2	-11.5	-1.3
KAH-3	66.3	+8.6	+1.0
KAH-2	61.5	+8.6	+1.0
OLA-2	60.1	+13.4	+1.6
OLA-3	58.3	+20.2	+2.3

a/ No  $\Delta \overline{\text{FCF}}$  is available at present for transect USR-3.

b/ Multiple of lowest rate of change, with rates at transects KAH-2 and KAH-2 taken as 1.

Table 6. Crown loss and functional crown foliage in girdled ohia trees.  
 (Means are based on 10 trees in each category. All trees are  
 located on the same site).

	Mean crown loss % May 1976	Mean crown loss % Sept. 1977	Mean functional crown foliage % Sept. 1977	Number of dead trees Sept. 1977
Check trees	12	16	67	0
Z-girdled trees	11	20	60	0
S-girdled trees	14	37	29	3

Table 7. Plagithmysus bilineatus activity in ohia slash. Basal portions of 20 trees were sampled at each site.

	Slash Location							
	TPR-3	OLA-1	PUN-3	WRR-2	USR-1	KAU-2	LAU-3	KAH-1
Date Cut	9/12/75	9/25/75	12/10/75	10/30/75	11/12/75	2/17/76	3/10/76	8/11
Interval Until Sampling (Weeks)	14	13	17	25	23	14	14	15
Total Length of Logs Sampled (m)	52.4	55.7	98.1	67.2	47.9	77.1	51.9	46.6
Log Surface Area Sampled (m <sup>2</sup> )	12.4	13.2	31.1	21.0	11.7	20.6	15.4	11.4
Total new galleries	228	276	164	60	2	14	6	170
New galleries w/ living larvae	210	245	139	39	1	13	0	150
$\bar{X}$ galleries /m <sup>2</sup> log surface	18.4	20.9	5.3	2.9	<0.1	0.7	0.1	14.9